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RECENT DEVELOPMENTS IN THE DESIGN
OF SMALL REFINERIES

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RECENT DEVELOPMENTS IN THE DESIGN OF SMALL REFINERIES

No.690

A.4.2.3.

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1. It should be the aim of all concerned that the economic development of a less developed area be handled in a manner that it will be self-sustaining and preferably self-generating. The key to this is that it produce products and services which are competitive with those available from elsewhere. An essential ingredient of such a development is energy, and thus the energy requirements must, in turn, be met in such a way as to be competitive. As the economy of less developed areas grows and the demand for energy grows, petroleum fuel products are relied upon in most instances to meet the energy needs. The problem of furnishing these products to the economy of less developed areas in an economic and competitive manner is the subject of this paper.

2. There are two routes which can be followed to do this:

- (a) Import of finished petroleum products.
- (b) Manufacture of such products locally from indigenous or imported crudes.

The advantages of off-taking and importing products from large, centralized refining installations are axiomatic. The cost of energy supplied by this route will be competitive since such products must be priced basically competitively through the free marketing areas. On the other hand, the route of manufacturing indigenously is not so clear-cut and is fraught with difficulties. Even though crude oil is purchased at competitive prices, the problem lies in the cost of manufacturing products from these crudes.

3. The difficulty arises from the fact that local requirements for products in a less developed area are small--extremely small, in fact--compared to the cumulative product take-off at the large refining facilities from which competitive areas may be obtaining their requirements. Unfortunately, large refineries are not really multiples of small units, but consist of essentially the same pieces of equipment built in larger sizes. Increases in capacity by this route can be obtained at relatively little increased cost and thus the cost of refineries is not proportional to size; rather, the cost increases more slowly than the size increases. Consequently, the larger refineries inherently require less investment and less operating costs per barrel of refined product. This puts the less developed areas, with their small requirements, at a great disadvantage when going the route of indigenous refining.

4. Sometimes there are compelling reasons for the indigenous refining route--to establish a local industry, relieve unemployment, conserve foreign exchange, etc. Tremendous incentives then exist to overcome the size disadvantage described above. It is possible to overcome the inherent size disadvantage and, as a target, make these installations truly competitive. Considerable effort has been spent

in developing principles and concepts which would permit the installation of very small refineries which would meet this target. Many of these principles have been demonstrated conclusively in recent installations, in which the so-called "divisor advantage" of large refineries has been completely eliminated.

5. The solution worked out in simplest terms was to treat small refineries differently from large refineries from both conceptual and engineering standpoints. The first step was to uncover the factors which established the cost of the small refineries. An analysis of many industry refineries showed that the key cost factors could be grouped into two broad categories. The first encompasses those factors or decisions which set the basis for the refinery design--these have been called "design basis decisions." The second category includes the factors and decisions made by the engineers who design and construct the refinery--these are called "technical decisions."

6. Very small refineries, for the purposes of this paper, are considered to be in the range of 2500 to 5000 B/D of products and should be capable of producing satisfactory products, both in yields and quality. The quality and quantity of such products may vary considerably, depending on the location and needs, and on the quality of the crude which can be made available. In terms of physical facilities, a refinery is considered to encompass the functions of crude receipt and storage, converting the crude into finished blend stocks, blending these into finished products, and storing and loading of products for shipment. Utilities, shops, and other associated facilities are also included within the scope of the term.

7. studies show clearly that the design basis decisions exert a major effect on refinery investment and it is imperative that the effect of such decisions on refinery investment be determined before investment decisions are made. The nature of these decisions and the influence of these on refining investment costs as determined from actual experience are covered below and in Figure 1. Figure 1 shows that a potential savings of 35% can be obtained if all these areas are decided in such a way as to be favorable to the manufacturing function and if such decisions are exploited by aggressive engineering. In most cases, a good portion of the savings can be captured.

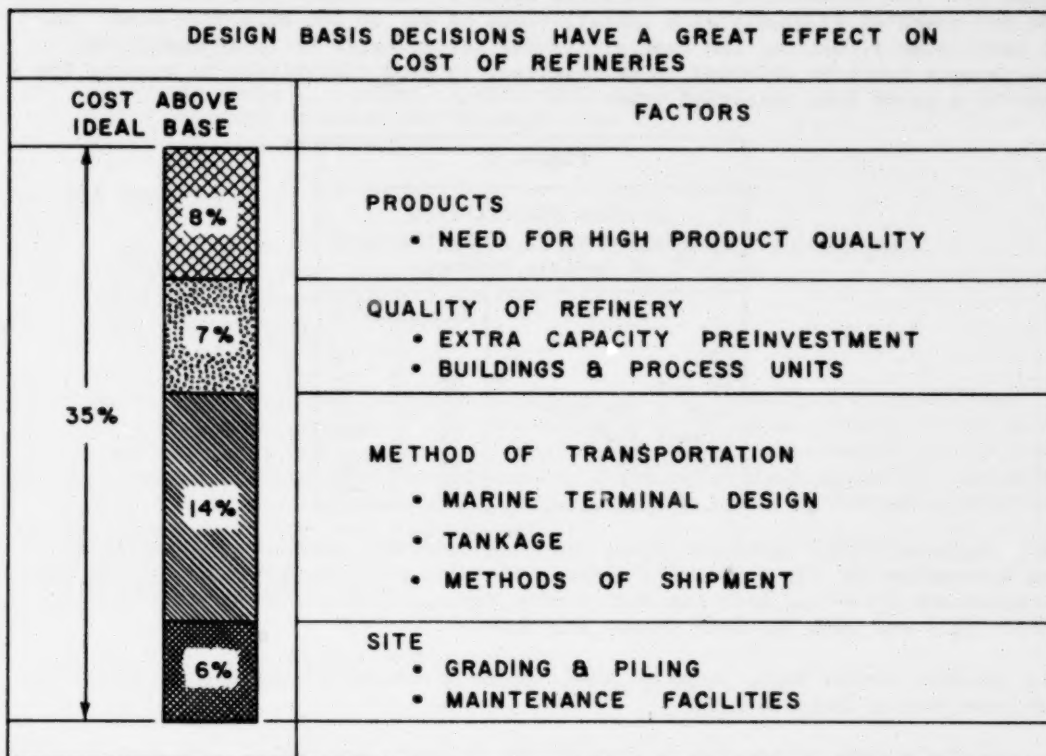
(a) Products - This includes the amount and quality of each product, all of which influence the nature and severity of the process facilities, as well as such items as utility and chemical requirements, materials of construction, etc.

(b) Quality of Refinery - This area covers the need for paved roads, nice office building, cafeteria, and other items which are unessential to the operation of the refinery itself; the degree to which risk acceptance is obtained; and the extent to which money is spent to meet future contemplated needs.

(c) Product Movement - Arbitrary decisions in handling of products can have a vast effect on costs. These items involve marine terminal design, railroad sidings, storage volumes, marketing terminals, size of shipments, etc.

(d) Location and Site - These fix the cost of the land; the leveling, grading, and filling; the necessity for piles; the availability of local facilities such as utilities, shops, transportation, etc. Local regulations which cover construction codes and water pollution, customs and taxes, are also extremely important.

FIGURE 1.



8. Given a set of carefully established design basis decisions, it then becomes necessary to apply sharp, imaginative engineering to these decisions in order to extract all of the economic potential available. This involves the following areas:

(a) Process Selection - This requires application of the best process to provide the desired product slate; getting the most out of the crude oil at minimum cost.

(b) Process Design - This area translates the process scheme into specifications which define the plants to be erected. This encompasses many engineering decisions - equipment selection and sizing, plant layout, materials of construction, provision for spare equipment, etc.

(c) Construction - This pertains to the translation of specifications into physical plant and requires efficient management and control to achieve optimum cost objectives. Many decisions are involved affecting the detail design, purchasing, and construction of the refinery; e.g., preparation of the many construction drawings, construction planning (manpower schedule), expediting and inspection of materials, construction management, etc.

9. The results of a recent study illustrate the principles outlined above.

The study involved building a refinery to market 4800 bbls./day of salable products. Two basic processing schemes were investigated as alternatives through the study: catalytic cracking (gas oils) and Hydroskimming (naphtha catalytic reforming). The 4800 bbls./day of salable products were made with each scheme, but with different product distribution (see

Figure 2). The investments and operating costs of both cases were essentially the same and compared favorably with installations of ca. 50,000 bbls./day size. In any particular situation, the case giving the better match to local marketing requirements could be selected; thus resulting in good flexibility in meeting the needs of a given less developed area.

Figure 2		
Product Distribution Hydroskimming Vs. Cat. Cracking % of Salable Products		
	H/S	C/C
LPG	2	2
Mo Gas	25	31
Kero & Jet Fuel	11	14
Diesel Fuel	24	30
Fuel Oils	38	22
	100	100

10. Since catalytic cracking refineries have been more expensive historically than Hydroskimming, the previous standard catalytic cracking plant (Model IV) was re-engineered in detail with remarkable cost savings (50% of the Model IV investment). This new unit has been termed the Model V.

11. In this design work, an exact scale model of the onsite facilities was made. Some interesting features are:

(a) The entire processing section of the refinery was fitted into a very small area, 80 ft. x 130 ft.

(b) All of the equipment was designed as one integral unit.

(c) All equipment, except the large towers and connecting piping, was skid-mounted.

(d) Packaged utility supply was provided in the unit so that it was self-sufficient from a utilities standpoint.

12. The above illustrates what the engineer can do in a given situation to achieve minimum costs. As indicated earlier, he is greatly helped in this work by the opportunities provided by the Design Basis Decisions. To clarify this picture, it is desirable to classify the many factors and decisions which set the design basis into one of three general categories: "local," "refiner," and "area-site." This classification is arbitrary in that most decisions are influenced by more than one category. Examples of Design Basis Decisions are given below:

(a) "Local"

- (i) Industrial planning.
- (ii) Emergency storage.
- (iii) Special product specifications.
- (iv) Customs, duties, taxes.
- (v) Labor education or training.
- (vi) Pollution regulations.
- (vii) Construction codes.
- (viii) Amenities.

(b) "Refiner"

- (i) Products ... number, quantities, qualities.
- (ii) Product movement and shipment size.
- (iii) Quality of refinery.

(c) "Area-Site"

- (i) Climate ... temperature, rainfall, hurricane, earthquake.
- (ii) Site proximity to sea and existing facilities.
- (iii) Site elevation, soil bearing.
- (iv) Water availability.
- (v) Labor availability.

13. The "local" attitudes, desires, regulations, and planning are established principally by the governments. The generation of a favorable climate in which the refiner and his engineers must work is economically sound. One method to achieve this is industrial planning. The allocation or zoning of land areas for industrial development which meet the needs of industry will help create a favorable climate. Such needs for a refinery are proximity to:

(a) Transportation

- (i) Sea.
- (ii) Docks (dry and liquid cargo).
- (iii) Railroads.
- (iv) Roads.

(b) City

- (i) Large consuming area.
- (ii) Available labor.
- (iii) Housing.

(c) Industry

- (i) Utilities.
- (ii) Shops.
- (iii) Chemicals.

Industrial planning can make many of these factors available and attractive. Also, an industrial zone will allow a refinery to be located with other industries so that less self-sufficiency is required.

14. The government's attitude and regulations affecting the refinery are also important. They may, e.g., require additional investment by demands for tankage over and above that required for processing, and for product quality over that actually required. The cost of metering product shipments for customs can vary from a nominal to high, depending on regulations set up by the government. Pollution regulations, construction codes, and amenities vary from location to location. It should go without saying that the refiner is interested in being a good neighbor and in having a safe refinery; therefore, he will automatically adopt safe and satisfactory codes and regulations if none exist. In so far as government codes and regulations are concerned, good ones are those which meet the local requirements and fit the country, refinery site, and size; that is, they are not adopted arbitrarily from elsewhere.

15. The small refiner must think and operate differently from the large refiner. The construction and operation of a small refinery must be turned to advantage. He must make use of the favorable fact that fewer and less sophisticated products are required in a less developed country. On the whole, decisions concerning the number, quantity, and quality of the products required establish the type, amount, and severity of processing. If the number of products are not low, he will be fettered with excessive investment--because each product requires, as a minimum, individual handling for storage, loading, and shipment. Also, he may find it desirable to import certain finished products to avoid inordinate processing costs. In this case, he can obtain a more economical plant and avoid excess products.

16. The refiner must also consider the quality of the refinery. Here again, the small size can be turned into an advantage. Optional design factors and pre-investment for flexibility, as well as convenience items and seasonal variations, can be reduced since fewer products are produced. Also, in the small refinery, the degree of risk acceptance can be increased. Risk acceptance refers to continuity of refining as influenced by equipment availability and the impact of the loss of a unit or the refinery if a fire or other catastrophe should occur. It is relatively easy to make up the output of a small refinery by importation of products. Self-sufficiency must be reduced by using facilities such as docks, water supply, electric power, shops, warehouses and offices which are furnished by others or shared with others.

17. The "area" establishes the importance of natural phenomena such as rainfall, temperatures, and presence of hurricanes and earthquakes. These must be accounted for in the design of the facilities. The specific "site" governs the elevation, grading, soil bearing, piling, and layout and can affect air and water pollution facilities. The site proximity to existing facilities and services such as piers, shops, railroads, utilities, and labor also plays a very important role in establishing the degree of self-sufficiency and thus the refinery cost. Every effort by all concerned must be made to have such areas set aside for this use.

18. In short, the "design bases" of a refinery are made up of the numerous decisions formulated by the local government, refiner, and engineer. These decisions are influenced by the area and site. With the variability in such items, the best decision for one location may often be the poorest decision in another location. An example of such a situation is found in the selection of cooling medium in the refinery; air, sea water, and fresh water cooling are each optimum for a particular site and climate.

19. In summary, if reasonable and favorable conditions exist in a country, such conditions being generated to a large extent by the local attitude and government, and if these favorable conditions are vigorously utilized by an experienced engineering organization, there is every reason to believe that the costs of an indigenous small refinery can be brought in line with those of much larger refineries. It is self-evident that the costs will depend on how many factors are favorable, on how well they have been used, and on how well the less favorable decisions are handled. However, it is reasonable to expect - and it has been demonstrated - that small refineries in the size range of 2500/5000 B/D can be built at a cost that compares favorably with the investment of refineries an order of magnitude larger. The operating and product costs will also reflect this investment reduction. It must be recognized that these small refineries are a different breed than the larger refineries and are custom-designed to meet the requirements of less developed countries. This philosophy and approach are essential for success.